

# Introduction: Ambidextrous open innovation in the 4<sup>th</sup> Industrial Revolution:

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**Abstract:** With the popularity of artificial intelligence (AI), big data, Internet of Things (IoT), business nowadays is featured with technology advancement, open innovation and collaboration. This happens particularly in the manufacturing sectors, known as the Industrial 4.0 or the 4<sup>th</sup> Industrial Revolution. Alongside this trend, also there is a movement towards servitization and service innovation. In the financial services sector, FinTech firms, traditional large firms, intermediaries, users, regulators are actively engaged together to develop smart system of banking, investing and insurance service. Nevertheless, the sector is facing challenges in relation to security, trust, and external disruptions. To solve this, first, this paper builds an ambidextrous open innovation model with multi-dimensions which are motivated by the arriving of the 4th Industrial Revolution. Second, this paper applies the ambidextrous open innovation model with multi-dimensions to the financial sectors to validate the model basically. Third, this model is applied to several researches to obtain additional validation of it.

*Keywords: Multi-dimension, Ambidextrous Open Innovation, the 4th Industrial Revolution, Financial sector*

## 1. Introduction: Research Question, Scope, and Method.

With the popularity of software engineering artificial intelligence (AI), big data, Internet of Things (IoT), business nowadays is featured with technology advancement, open innovation and collaboration. Meanwhile open business model and customers experience are recognized, bringing changes to industries and the society (Lee et al., 2018). This is known as the Industrial 4.0 or the 4<sup>th</sup> Industrial Revolution, as opposed to the Industrial 1.0 featured by the using of steam power and machinery, Industry 2.0 featured by the adoption of electric power and assembly line, Industry 3.0 with the introduction of

computer and the Internet. The term Industry 4.0 was originated in 2011, and formally introduced as “Industrie 4.0” by the German government in 2013 with the purpose of enhancing the German competitiveness in the manufacturing sectors. In 2016, Klaus Schwab, founder and executive chairman of the Geneva-based World Economic Forum (WEF) raised the “The 4<sup>th</sup> Industrial Revolution” as the most important concept. Rather than certain technology invention, it encompasses a range of technologies that bring together the physical, digital and biological worlds and will be felt across all industries and economies (Klaus Schwab, 2017).

*“The changes are so profound that, from the perspective of human history, there has never been a time of greater promise or potential peril. My concern, however, is that decision-makers are too often caught in traditional, linear (and non-disruptive) thinking or too absorbed by immediate concerns to think strategically about the forces of disruption and innovation shaping our future.”*  
(Klaus Schwab, 2017)

Though the term varies cross the global, Industrial 4.0 shows the technology transformation towards digitalization, automation and servitization. For example, the UK government has issued the policy paper Industry Strategy to promote idea, people, infrastructure, business environment and places (Gov.UK, 2017). At firm level, Industrial 4.0 can be interpreted as product customization, digitalization, big data, and the use of industrial robots and 3D printing technology for product design, development, and partnership (Volkswagen, 2019). Industrial 4.0 not only applies to traditional manufacturing sectors, but also significantly restructures the services sectors. Among them, the financial services experience technology advancement, with direct impact seen in terms of online payment, online forex trading and digitalization. The smart system, machine learning, blockchain, and FinTech have connected business of all sizes, regulators, agencies and users together, aiming for a flexible, responsive and sustainable innovation ecosystem. New business models such as open banking and open insurance have emerged. Regional innovation ecosystem is formed with the support of government and independent regulation institutions, the collaboration between private and public sectors, technology platform and user engagement. This analogy is sometimes referred as Finance 4.0 by practitioners with characteristics of personalization of product and service, open innovation, digitalization and collaborations towards sustainability. Unlike Industrial 4.0, the concept of Finance 4.0 is still under development. According to Asia Development and Property Technology (ADAPT, 2018):

*“Finance 4.0 is all about using digital technology to make better use of finances and financial data. Finance 4.0 promises to change the face of the world of finance as we know it. There are many changes that will come because of it, not just in terms of technology but also the regulations governing the financial industry.”*

The term Finance 4.0 also demonstrates the evolution from Finance 1.0 as seen in the traditional banking system, to Finance 2.0 with the rise of credit and equity market, to Finance 3.0 with data analysis process management, and recently towards the digitalization and network on a large scale (ADAPT, 2018). Financial services especially rely heavily on trust and security. Meanwhile it is challenged by disruptive factors globally such as technology changes, economic crisis, regulations, and the recent Covid-19

pandemic.

So, how about the dynamic changes of open innovation in the 4<sup>th</sup> Industrial Revolution?

Our paper aims to answer to this research question. First, a multi-dimension model showing the ambidextrous open innovation in the 4<sup>th</sup> Industrial Revolution is developed from literature reviews. Second, the model is applied to the financial services sector in the UK. Based on document review especially from the professional reports, informal interview and a focus group study with 12 employers and employees from the UK financial services sectors, this paper highlights five main features and challenges of the multi-dimension of ambidextrous open innovation in the context of Industrial 4.0 with details: 1) Customization, digitalization and user interaction; 2) Process technology advancement and the blooming of Fintech; 3) Open innovation and open finance models; 4) Regulation support at the regional and global levels; 5) Changes in response to the COVID-19 pandemic disruption. Third, the multi-dimension model of ambidextrous open innovation is applied to several researches as meta-analysis to validate this model again.

## **2. Literature review and model building**

### **2.1. Literature review**

Originally, Chesbrough proposes inbound open innovation which means that firms take technology for innovation from outside, and outbound open innovation through which firms send any non-using technology for other firms' usage, but they are not separated from each other as "open innovation combines internal and external ideas into architectures and systems whose requirements are defined by a business model"(H. W. Chesbrough, 2003, p. 24). In fact open innovation process can have three archetypes: 1) Firm outside-in process type, which explores external knowledge and locus of innovation occurs inside the company; 2) Firm inside-out process types, which exploits innovation inside the company at locus of innovation is outside the company; 3) Firm coupled process type, which pursues rear ambidextrous open innovation by joint innovation and exploitation (Gassmann & Enkel, 2004). There are a lot of discussion on the exploration as inward open innovation, and the exploitation as outward open innovation from March to Vanhaverbeke. Two types of exploration and exploitation are identified as: 1) cross-functional exploration from product-market knowledge to technology, from technology to science, exploitation from science to technology, and from technology to product-market knowledge; and 2) within functional scientific exploitation or scientific exploration technological exploitation and technological exploration, product-market exploitation and product-market exploitation(Li, Vanhaverbeke, & Schoenmakers, 2008; March, 1991). Most importantly, according to testing for the performance effects, the balance between exploitation and exploration shows high long-run performance, and additionally high exploitation with high exploration also motivate long-run performance (Gupta, Smith, & Shalley, 2006). Some of the relevant open innovation costs (cognitive, transactional, and organizational costs) can be reduced by combining knowledge inflows (inbound open innovation), and outflows (outbound open innovation) because ambidextrous open innovation can motivate creative results under the control of open innovation cost known as complexity (Cassiman & Valentini, 2016; Yun, Won, & Park, 2016). Thus, some research groups propose lists of individual interdisciplinary and ambidextrous competencies, and organizational competencies for open innovation as a new research agenda (Hafkesbrink & Schroll, 2014). In essence, if a firm does not have enough ambidextrous high-tech cluster (like the Silicon Valley), especially the ties to venture capital firms and start-ups, it is not easy for the firm to outsource exploration through an Acquisition and Development

(A&D) strategy of start-ups and exploitation specialization (or inbound open innovation activities in high-tech SMEs), and this can be more innovative and competitive than an ambidextrous organization (Ferrary, 2011; Parida, Westerberg, & Frishammar, 2012). Citizen innovation which explores the responsibility governance and cooperative model of a “Post-Schumpeter” Paradigm, or social open innovation which combines social requirement and market innovation motivation may include inbound and outbound innovation together when pursuing sustainable innovation with an holistic model of business ecosystem, or a business model innovation through a rectangular compass (Chen, Han, & Qu, 2020; Shi et al., 2021; Yun, 2015; Yun & Zhao, 2020).

In addition, a framework to spur innovation and growth is proposed with four factors: 1) thinking of your business as a service business; 2) co-creating with your customers; 3) extending services innovation outside your organization; 4) transforming your business model with services (H. Chesbrough, 2011, p. 29). More and more corporations throughout the world are adding value to their core corporate offerings through services, and this trend is exaggerated alongside the 2<sup>nd</sup> information technology revolution (Vandermerwe & Rada, 1988). Servitization as a shift from selling products to selling an integrated combination of products and services that delivers value in use, embracing the way to design the competitive integrated product-service offerings in the context of an industrial organization (Baines, Lightfoot, Benedettini, & Kay, 2009). There are five options for servitization, all of which are motivated by the 4<sup>th</sup> Industrial Revolution: 1) integration oriented product-service system (PSS), 2) product oriented PSS, 3) service oriented PSS, 4) user oriented PSS, and 5) result oriented PSS (Neely, 2008). There are detailed differences between servitization, and service infusion even though both can be included in the general trend of servitization, and motivated by the 4<sup>th</sup> Industrial Revolution. Servitization means the transformation of all processes whereby a company shifts from a product-centric to a service-centric business model and logic. Service infusion means the process whereby the relative importance of service offerings to a company or business unit increases, amplifying its service portfolio and augmenting its service business orientation (Kowalkowski, Gebauer, Kamp, & Parry, 2017).

In 2011, Rifkin proposes that the 3<sup>rd</sup> Industrial Revolution is opened by the confusion of IT, and the Internet with the transformation to renewable new energies or energy systems such as hydrogen energy, global energy sharing grid, electronic and fuel cell car, continental smart energy grid system etc., which is totally different from the 2<sup>nd</sup> Industrial Revolution. The 3<sup>rd</sup> Industrial Revolution in its governance rule is the parallel with collaboration, which is opposite to the hierarchy structure with competition of the 2<sup>nd</sup> industrial revolution (Rifkin, 2011, p. 59). Klaus Schwab at the 2016 World Economic Forum announces that the 4<sup>th</sup> Industrial Revolution is the revolutionary change of all industries featured by new business models, disruption of existing system, rearrangement of production, consumption, delivery, and distribution from the 21<sup>st</sup> century. And it is triggered by the digital innovation, AI, robot engineering, IoT, autonomous car, 3D printing, Nano technology, life engineering, quantum computing, blockchain, or new biological technology including synthetic biology, genetic markets, bioprinting etc. (Klaus Schwab, 2016). The 4<sup>th</sup> Industrial Revolution is developed upon the 3<sup>rd</sup> Industrial Revolution, the digital revolution that has been occurring since the middle of the last century. Since then, there are possibilities of billions of people connected by mobile devices, with unprecedented processing power, storage capacity, and access to knowledge, and these possibilities will be multiplied by AI, IoT, autonomous vehicles, 3D printing, nanotechnology, biotechnology, or quantum computing (K. Schwab, 2015). Human ingenuity and transformation processes dedicated to sustainability in this the 4<sup>th</sup> Industrial Revolution will open up new opportunity spaces, thereby combining an increase in economic welfare and social justice with a reduction of negative environmental impact such as world turned upside-down with entrepreneurial

decline (Philip Cooke, 2019; Andreas Pyka, Bogner, & Urmetzer, 2019).

## 2.2. Concept model building

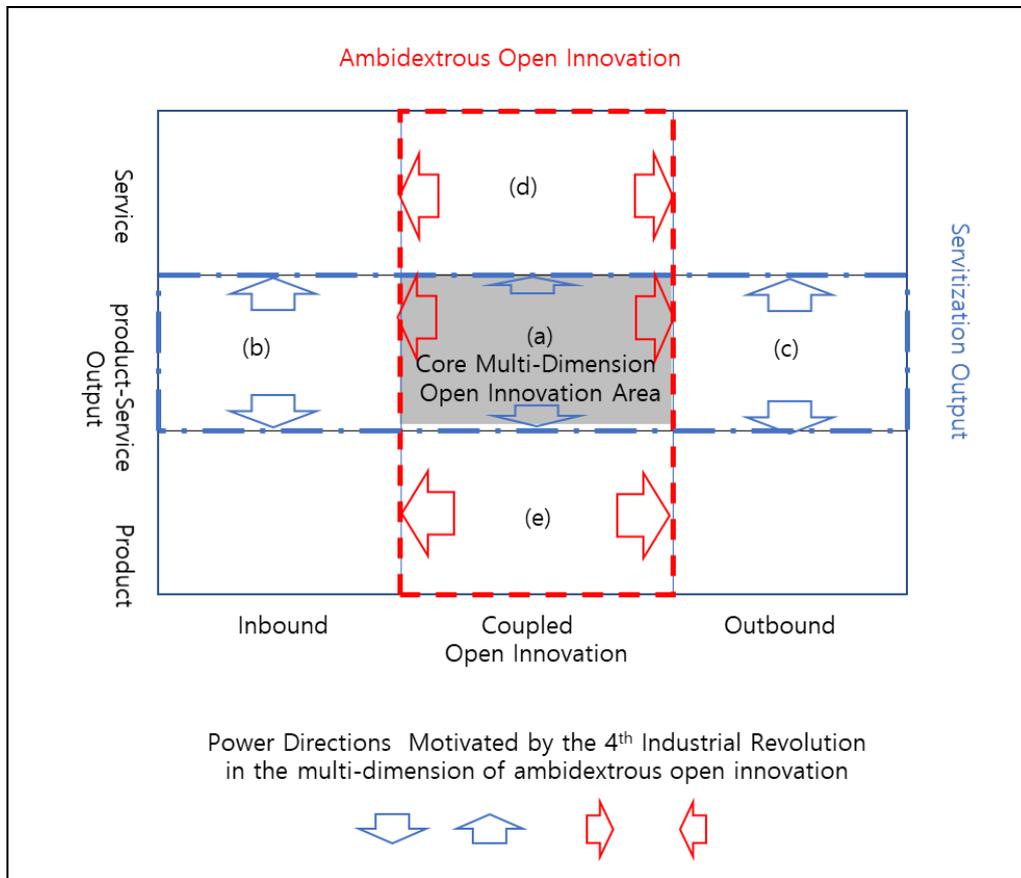


Figure 1. Multi-Dimensional Ambidextrous Open innovation in the 4<sup>th</sup> Industrial Revolution

We proposed the multi-dimensional ambidextrous open innovation model in the 4<sup>th</sup> Industrial Revolution (the MD ambidextrous OI in the 4<sup>th</sup> IR) as figure 1. The 4<sup>th</sup> Industrial Revolution with digital revolution and new technologies will motivate more active inbound and outbound open innovation together than before. In addition, it will trigger more servitization because of the global wider and faster networking in IoT, quantum computing and others in the marginal cost zero society (Rifkin, 2014). Meanwhile, the 4<sup>th</sup> Industrial Revolution will expand across all directions from (a) to (e). The core multi-dimension open innovation area, (a), meaning the MD ambidextrous open innovation area will be expanded specially. It is because the motivating of ambidextrous open innovation by the 4<sup>th</sup> Industrial Revolution with the triggering of servitization will promote the growth of the core multi-dimension open innovation area.

### 3. Applying Multi-dimension Ambidextrous open innovation to the financial service

#### 3.1. Customization, digitalization and use interaction

One of the features in Industrial 4.0 is the customization of products and service. Users are no longer passive buyers, but are actively engaged in user experience and product development (Yun & Liu, 2019). The financial services sector particularly relies on service quality and customer relationship, to both individual customers and corporate clients. As participants in the focus group study pointed out:

*“Wider range of services become one competitive advantage. User experience such as using mobile Apps also changes the financial services sector.”*

*“Services targeting older people, vulnerable and disadvantaged people are concerned more and more by companies. In other words, innovation should also be inclusive and sustainable.”*

The adoption of smart technology in payment becomes a trend in consumer behavior, which provides flexibility, convenience and efficiency. Apart from smart payment, peer-to-peer lending, crowdfunding platforms (e.g. equity-based crowdfunding, reward-based crowdfunding, profit sharing crowdfunding, donation-based crowdfunding), and invoice trading are alternatives to conventional financial service and additional resources, where bank credit products are unavailable or too expensive (Bilan, Rubanov, Vasylieva, & Lyeonov, 2019). However, it is argued that the development of alternative peer-to-peer financial services are influenced by the regulation, as seen in the cases of China with more restriction and UK with more support to SMEs (Bilan et al., 2019).

User experience comes together with the digitalization of financial related products. According to the Deloitte Center’s survey to 17100 banking consumers across 17 countries in 2018, consumers favor banks which provide better quality, convenience, and value via an exceptional digitally driven consumer experience such as online banking interaction (Srinivas and Ross, 2019). Digital adventurers demonstrate the highest levels of satisfaction with their banks, compared to traditionalist (light digital users), and online embracers (Srinivas and Ross, 2019). It is suggested that restructuring organizations around different stages of customer interaction is the next stage for the financial services sector (Srinivas and Ross, 2019).

By customization, and user interaction with digitalization, the financial system in the 4<sup>th</sup> Industrial Revolution, inbound open innovation (which means the new technology or idea from out of financial system comes into the bank, and makes innovation such as customization, and user interaction) and outbound open innovation (which means knowledge and technology from the financial system goes out the bank, and makes innovation such as customized marketing and e-commerce etc.) tend to occur together. In addition, the digitalization of the financial sector is motivating more active servitization through smart banking Apps with the AI, and machine learning algorithms.

### *3.2. Process technology advancement and the blooming of Fintech*

Under Industrial 4.0, innovation ecosystem is largely promoted by new technologies, including AI, robotics, big data, IoT, and 3D printing. This also happens to support the financial services sector, as The City UK (2020) report reveals that 65% of UK’s financial institutions have changed their strategies due to technology-related disruption. Unlike the manufacturing firms under Industrial 4.0, computer integrated automation process does not apply to the finance services sector. Instead, there is a gradual change in management process with digitalization and machine learning. Below shows the opinion from a participant from the UK financial services sector:

*“Technology is the biggest driven force under the Industrial 4.0. Robotic technology, data analysis, and software engineering are particularly essential to the financial services sector. It also changes the relationship between companies and customers dramatically. For instance, more and more services are now delivered through the tablet, Internet and mobile phones.”*

From technology advancement aspect, FinTech particularly encompasses innovation in financial technology with a diversity of organization involves, such as large firms, SMEs and start-ups, together known as Big Tech (TheCityUK, 2020). FinTech also covers sub-sectors, including RegTech which means the adoption of technology to facilitate regulation delivery (FCA, 2015), Wealth Tech, PayTech, InsurTech, aiming for an innovation network and ecosystem. Meanwhile, with recent technology advancement of digitalization, big data, and IoT, digital and platform innovation based on the Internet becomes an emerging stream of innovation to transform business and social relationships with openness, affordances, and generativity (Nambisan, Wright, & Feldman, 2019). Using digital platform, financial companies not only connect closely with customers, but also bring service providers and stakeholders together to exchange knowledge and create value (Pollari, 2018). This multi-sided platform can be recognized as an ecosystem (Pollari, 2018). In a board meaning, an innovation ecosystem has expanded the scale of innovation from organizational, to inter-organizational, and to national or regional levels involving multiple innovative actors. It refers to “the complex relationships that are formed between actors or entities whose functional goal is to enable technology development and innovation” (Jackson, 2011). Inside the ecosystem, knowledge creation, development, transfer, and exchange are operated among economic agents and non-economic parties such as technology, institutions, sociological interactions, and culture (Mercan and Goktas, 2011). With digital and platform-based innovation ecosystem, banks no longer complete on the traditional value chain, but seeking growth opportunities through engaging with stakeholders, differentiating customer experience, collaborating with more partners, and delivering new forms of value (Pollari, 2018). Thus, the blooming of Fintech is also motivating servitization based on the ambidextrous open innovation.

### *3.3. Open finance models*

While traditional large firms develop in-house R&D capability, and protect IPR, open innovation suggest firms break boundaries and exchange knowledge (H. W. Chesbrough, 2003). Open innovation is defined as “the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively. [This paradigm] assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as they look to advance their technology” (H. Chesbrough, 2006). Though some argued that open innovation is built upon existing concept such as the network model of innovation (Rothwell, Rothwell, and Zegveld, 1985). A survey in 2014 reveals that large firms in Europe and the U.S.A. continue to adopt open innovation (H. Chesbrough and Brunswicker, 2014). Among them, inbound activities include idea competition, consumer co-creation, supplier innovation award, crowdsourcing, and outbound activities such as corporate incubation, patent selling, and joint-venture showing increasing trend (H. Chesbrough and Brunswicker, 2014). According to IBM, open innovation in business means collaborative development, using open source licensing, open governance, and open standards to create an ecosystem

(Wieck, 2019). Blockchain in the financial services sector enables peer-to-peer transaction in a decentralized way, connecting business with vendors and enabling innovation ecosystem (Wieck, 2019).

Open innovation can be seen in the open banking and open insurance. For instance, open banking as a new business model, connect consumers and SMEs with access to a diversity of financial product and services. With mobile Apps and open banking technology, customers are able to compare and select services including personal finance management, viewing accounts in one place, managing debt, sharing information securely with banks, building societies and other financial companies under the regulatory standards (Openbanking, 2020). Open banking also provides approaches for business to manage cash flow (Openbanking, 2020). The nature of information sharing and openness revolutionizes the way of managing and controlling money and financial information. Collaboration and joint venture across all sizes of organization is another important business model in the financial services sector, for resource acquiring and sharing (TheCityUK, 2020). This demonstrate a coupled open innovation model with a combination of inbound knowledge acquisition and outbound commercialization approach. Interestingly, participants in the focus group study highlighted the importance of collaboration.

*“Collaboration is certainly an on-going trend. Apart from formal collaboration such as joint venture, informal network for knowledge sharing and learning is also essential.”*

*“Companies can focus on their core competence and acquire expertise from elsewhere through partnership.”*

Broader ways of collaboration are also seen in the case of FinTech Alliance, where the Department for International Trade (DIT) works with UK FinTech companies for resources sharing through a centralized platform, forming a dynamic innovation ecosystem (TheCityUK, 2020).

#### *3.4. Regulations support on the regional and global level*

Science, technology and innovation (STI) related policies provide direct subsidies, facilitating linkage, clusters and networks, stimulating demand, creating entrepreneurship, and promote learning in the innovation system (Schot and Steinmueller, 2018). In general, STI policies have gone through Frame 1.0, 2.0 and 3.0. Policy 1.0 aims to promote production and technology generation, whereas Policy 2.0 links the knowledge supply with market demand (Schot and Steinmueller, 2018). Policy 2.0 is also recognized as policy and regulations to enhance the national systems of innovation (NSI) (Schot and Steinmueller, 2018), linking with the quality of the national education system, industrial relations, quality of technical and scientific organisations, government policies and cultural traditions (Freeman, 2002). While Policy 1.0 and 2.0 are under historical content, Policy 3.0 provide links to contemporary social issues and sustainability (Schot and Steinmueller, 2018).

As for the financial services sector, there has been more strict control with complex permission and authorization from the regulators, which can be independent from the government. Taking the UK for example, regulations have been formed by the government and Financial Conduct Authority (FCA). Regulations sometimes can be barrier to innovation and market expansion. According to the TheCityUK (2020), the unclear guidance from regulation make it difficult for existing firms and new entrants to be engaged in the innovation activities. Therefore, recommendations are made for the regulators to provide

clear guidance, working with industry to issue standardization and assessment criteria, and sharing best practice through forum and network (TheCityUK, 2020).

Traditionally regulations in relation to IPR protection are highlighted in large firms to maintain its competitiveness in the closed innovation regime (H. W. Chesbrough, 2003). In the context of Industrial 4.0, digitalization and information sharing become a trend. To enable the security and trust, data security and Cyber Security become critical business issues. With the application of technologies and processes, Cyber Security aims to protect computer systems from unauthorized access, reducing the risk of attack and damage.

In the financial services sector, the Digital Sandbox is an effective technology to ensure data security and enable firms to meet investors in a safe environment. According to FCA (2020), the Sandbox shows the features of access to high-quality data assets and regulation support, regulatory call-to-action (FCA, 2020). It can also facilitate a collaboration platform with firms, and interaction with policies and vendor marketplace safely (FCA, 2020). However, the investment and implementation of Sandbox can be a burden for SMEs, and a regulation to support network and partnership should be encouraged (TheCityUK, 2020). Rather than a decentralized local regulation system, it is also recommended a centralized regulations and supervisory framework supporting the integration of Innovation Hub (e.g. Bank of England Innovation Hub) expertise can reduce the risk (TheCityUK, 2020). On a wider infrastructure level, cross-border collaboration and the support of creative culture and entrepreneurship as regulation governance is required to foster the innovation in the financial sector with the ambidextrous open innovation and servitization of the traditional financial service, and products.

### *3.5. Changes in response to the COVID-19 pandemic disruption*

Apart from the above factors, Industrial 4.0 overall witnesses the emergence of disruptive new combinations between technology and the market (M. Lee et al., 2018). At the industry level, the competitive position relies on the forces of supply, buyer, rivalry, substitutes and new entrants (Michael, 1979). At the macro level, external disruption can come from regulation, economic, political, sociological, environmental, and technological factors. Crisis such as the current Covid-19 pandemic influences every aspect of the business and society, from consumer behavior, to sales and marketing, and to supply chain including financial industry. Studies suggest that companies believe crisis can bring new opportunities of grow, however, the innovation activities can be deprioritized in some degree. Instead, conserving cash and minimizing management, shoring up their core business, pursuing known opportunity spaces can be important (Am, Furstenthal, Jorge, and Roth, 2020). Given the risk and uncertainty, companies can achieve complete advantages through adapting the core to meet shifting customer needs, and reevaluating the innovation initiative portfolio, and providing new offers (Am et al., 2020). From the focus group discussion, new issues such as the promotion of online service and mobile banking, technology development which are mainly located in the multi-dimensional open innovation area (a) in Figure 1 are highlighted in the financial services sector due to Covid-19 pandemic. During the focus group study, participants from the UK financial services sector admitted the challenges, as well as opportunities for changes in response to the external disruption:

*“Thanks to digital technology, the financial services sector can still run remotely. Meanwhile, there are more potentials to promote internet banking and mobile system related service.”*

*“Companies and regulators should work together, sharing information and experience, to recover from the Covid-19 challenges.”*

*“Covid-19 pandemic has significantly changed the business model, process, technology and relationship with customers. It brings the business and society together, seeking for resilience and sustainability in a self-managed manner. Maybe it can be a drive force for the next industry revolution – Industrial 5.0?”*

It is yet early to predict the long-term impact of Covid-19 to the financial services sector, however, technology advancement can bring process, product and business model changes in both incremental and radical ways. Collaboration and information sharing become more important to solve the problem together. Digital Sandbox initiated by the FCA (2020) aims to support UK firms to recover from the Covid-19. Apart from it, as Innovation Policy Frame 3.0 addresses sustainable issues in principal, CSR, sustainability, and social innovation in the Covid-Pandemic 19 also transform the financial services sectors as emerging themes (Schot and Steinmueller, 2018).

In sum, the Industrial 4.0 is not only applied to the manufacturing sectors which generate tangible products, but also is more adjusted to the service sectors such as in the case of financial service sectors, known as the high servitization. The impact can be seen from aspects of product, service, processe, business models, market position and infrastructure with diverse inbound and outbound open innovation together, as shown in Table 1.

Table 1: The impact of Industrial 4.0 on the financial services sector

		Innovation aspect	Servitization Output	
			Industrial 4.0 in the manufacturing sector	Industrial 4.0 in the financial services sector (Finance 4.0)
Ambidextrous Open Innovation	Inbound/ Outbound	Product/Service	AI, Industrial robot, Driverless car, Customized product	AI, Machine learning, Customized service (individual/corporate), User experience, Cyber currencies (e.g. Bitcoin)
		Process technology	Smart factory, Cloud computing, 3D printing, 5G, IoT, Digitalization, Big data, Process automation, Virtual reality, Supply chain and logistics management technology	Smart system, Cloud computing, Digitalization, Big data, FinTech, WealthTech, InsurTech, Distributed ledger technology (DLT) (e.g. Blockchain)
	Outbound	Business model	Open software	Open banking, Open

			Cloud sourcing, Partnership	insurance, Partnership, Joint Venture
		Market position	Sustainability (e.g. electric car), Green factory, CSR	Social innovation (e.g. service for poor/disadvantaged group), CSR
	Inbound	Infrastructure and System	Cyber security, Intellectual Property Rights (IPR) protection, Innovation policy, National innovation system, Globalization	Digital sandbox, RegTech Localization, Globalization Social credit system (e.g. China)

#### 4. The Editorial; Validating the multi-dimensional open innovation

Based on the above exploration and analysis, it is clear that Industrial 4.0, digitalization and AI affect more and more on the service and emerging new sectors. To resolve the challenges of resource constraint, regulation challenges, security and trust, and disruption from Covid-19, there is a need to implement a multi-dimension open innovation. Additionally, to validate the multi-dimension open innovation, we have analyzed SOI 2020 special issue papers of Science, Technology, and Society. All special issue papers are linked with the key theme - *Ambidextrous Open Innovation of Science, Technology, and Society*. Through the analysis, we want to contribute to the theory of innovation, providing new views of how product innovation, business model, service innovation, and social innovation should be conducted in the context of ambidextrous open innovation and the 4<sup>th</sup> Industrial Revolution. Altogether nearly 170 papers were originally presented at the Society of Open Innovation: Technology, Market and Complexity (SOI) 2020 annual conference. Among them, 5 papers have been recommended and eventually published at the special issue

The first paper analyzes the collective intelligence in developing patents as the creative way from knowledge to open innovation. This study is based on the synergy in knowledge-based innovation systems at national and regional levels, and open science as challenges for sustainable science-society social contract in addition to collective intelligence in the incremental innovation (Krishna, 2020; J.-Y. Lee and Jin, 2019; Leydesdorff, 2018). The collective intelligence can be a new channel of ambidextrous open innovation, and servitization from two-side platform.

The second paper studies the evolution of open innovation by value-based network perspective with the case of Korean smart home industry. Opposed to the actor-based mode which focuses on innovation at the actor level, value-based mode of innovation looks at innovation at the value-level such as ambidextrous open innovation with servitization which will add value across various dimensions. This study is based on several ideas such as: integrating universities and business in digital age; Silicon Valley imperialism on smart city; the effect of service innovation on R&D; learning mode, incessant transformation, and demand articulation in the 4th Industrial Revolution; smartness of smart cities; dedicated innovation system and productivity slowdown; and dynamics from open innovation to evolutionary change (Becker and Eube, 2018; Philip Cooke, 2020; S.-j. Kim, Kim, Suh, and Zheng, 2016;

Fumio Kodama, 2018, 2019; Fumio Kodama and Shibata, 2015; Lara, Da Costa, Furlani, and Yigitcanla, 2016; Andreas Pyka, 2017; Andreas Pyka and Bogner, 2019; Yun et al., 2016).

The third paper analyzes factors influencing on technology transfer in companies at emerging economies, and finds out the holistic approach on different impact of factors which have direct relations with ambidextrous open innovation and servitization. This study is based on ideas such as: the technology commercialization capability from technology development capability; sustainability and continuous improvement of organization; the relation between R&D expense to turnover; and open innovation with fuzzy cognitive mapping(H. Kim, Park, and Joh, 2019; Medne and Lapina, 2019; J.-H. Park, Lee, Moon, Kim, and Kwon, 2018; Quiñones et al., 2019).

The fourth paper focuses on the optimal diversification strategy in pharmaceutical industry from the opposite two perspectives of balance-centered and hetero-centered. The paper implies the level of multi-dimension of ambidextrous open innovation. It is based on several studies including measuring the efficient of US pharmaceutical companies and adjusting net present value technology valuation model (Shin, Lee, Shin, and Kim, 2018; Woo et al., 2019).

The fifth study explains technology evolution and multiplier innovation through TDNA analytical model with diverse ambidextrous open innovation and servitization approaches. This study is based on the background of technology evolution, governance and convergence, and open innovation in knowledge cities (Almgren and Skobelev, 2020; H. S. Park, 2017; Yun, Jeong, and Yang, 2015).

## 5. Conclusion

### 5.1. Implication

With the popularity of AI, big data, IoT, business in the 4<sup>th</sup> Industrial Revolution is featured with the inbound-outbound ambidextrous open innovation and servitization with the fusion of product and service. Our paper focused on the impact of the 4th Industrial Revolution on ambidextrous open innovation and servitization from the concept modeling building by literature review, and applying the model to the UK financial sector and various studies of open innovation. In other words, this study proposed ‘the multi-dimensional open innovation of ambidextrous open innovation with servitization’ as a representative effect of the 4<sup>th</sup> Industrial Revolution on economy.

### 5.2. Limitations and Future Research Topic.

According to the findings, future discussions can be conducted from the following three perspectives: 1) ambidextrous open innovations between product open innovation and service open innovation; 2) ambidextrous open innovations between exploration and exploitation; 3) ambidextrous open innovations between political economics or market, and engineering. More diverse researches are required to find out the economic effects on the 4<sup>th</sup> Industrial Revolution.

Additional business sectors related field researches are needed to investigate the theme of “the multi-dimensional open innovation of the ambidextrous open innovation with servitization” with different aspects, characteristics, and effects, which can be generalized or categorized theoretically.

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